CHAPTER FOUR

FULL-SCALE DEVELOPMENT PHASE
(Pre-Milestone III)

INTRODUCTION

Following Milestone II, actual system development begins. Full-Scale Development (FSD) is the phase in which the system design is completed and a system prototype is built and tested in the intended Fleet environment. In the FSD phase, the system requirements which were established as system and equipment functions at Milestone II are developed into firm product specifications (drawings, schematics, and manufacturing instructions) and actual hardware and computer programs. The logistic support system design, which was established in the Integrated Logistics Support Plan (ILSP) and Logistics Support Analysis Record (LSAR) at Milestone II, is updated and implemented for operational testing and the transition to production. The equipment designs are tested by the contractor for design evaluation and operational qualification. The system and logistics elements are tested in the Fleet by the Program Manager. Finally, the system is delivered to a Fleet representative (OPTEVFOR) for a full operational test which will support the production decision at Milestone III.

Figure 4-1 describes the major activities related to A_o during the FSD phase. Successful completion of these activities leads to obtaining Approval for Full Production (AFP) which is necessary for going into production.

The FSD phase actually consists of three types of activity. First, the functional specifications established at Milestone II are transformed into firm designs and product specifications. Engineering analysis for reliability, maintainability, and supportability are conducted by the Program Manager in this subphase of FSD. Most of the analytical activities which are conducted for A_o during FSD are related to logistic support. Maintenance actions, times, levels, locations, and requirements for spares and repair parts, facilities, personnel, training, training equipment, technical data, tools, and test equipment are refined for established configurations. The ILSP is expanded to reflect the activities for test support, pre-operational support, implementation of each support element, and to establish performance and reporting requirements for monitoring ILS progress.

Second, supportability characteristics are tested in FSD. Limited elements of the logistic support system (test equipment, spares, technical manuals) are produced for tests which include the evaluation of the logistic support system against its specification and to support Development Tests/Operational Tests (DT/OT). Service tests are conducted in the planned operational environment to verify mission and equipment support system compatibility, and the sufficiency of support planning and implementation. Deficiencies found during test and analytical efforts (LSAs) are corrected by engineering changes or by changes in the support plan.

Third is the operational testing of the complete system design. Initially, an Engineering Development Model (EDM) or pilot production unit of the system is tested under realistic operating conditions. This is the first opportunity for realistic tests and evaluation of system supportability factors. Finally, a prototype of the system is delivered to the Fleet representative and is tested in the actual mission environment.

Because we have extensively discussed Sponsor responsibilities related to the basic reliability, maintainability, and supportability issues which must be resolved prior to deployment of

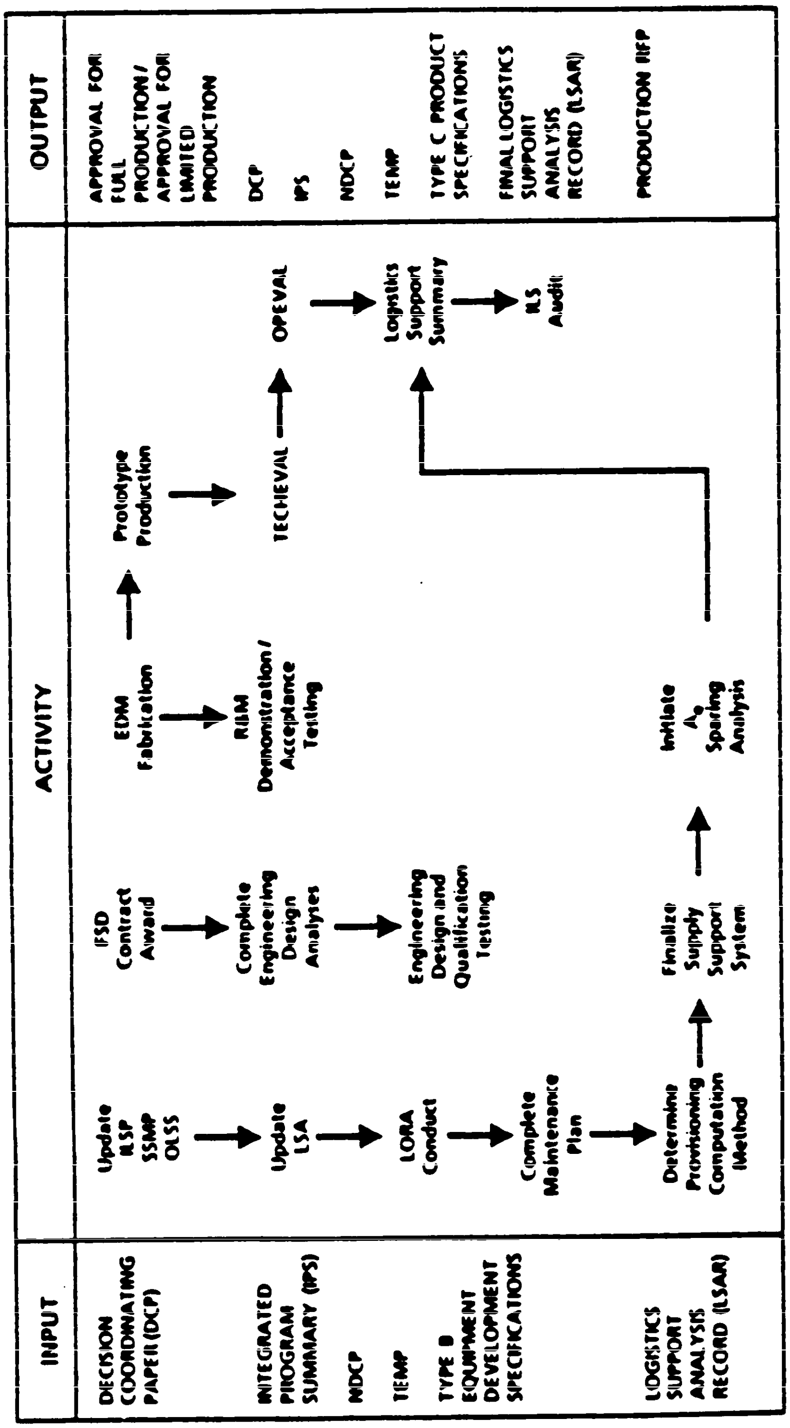


FIG. 4-1: FULL-SCALE DEVELOPMENT ELEMENTS

the system, this chapter will focus primarily on the importance of testing and on the Sponsor's role in structuring and evaluating test results.

REFINING THE A_o REQUIREMENT

Key Action Steps

During the Full-Scale Development phase, the Sponsor must ensure that three major actions are completed to refine the A_o requirement:

1. Finalize System Design and Logistics Support Plans

First, equipment/system definition must be completed together with the finalization of logistic support plans.

2. Complete Developmental Testing

Second, developmental testing must be conducted, typically by the Developing Agency or a contractor to verify reliability, maintainability, and supportability parameters for the system. Developmental testing demonstrates that the system design meets its specifications in performance, reliability, maintainability, and logistics. The early phases of developmental testing comprise a formal Technical Evaluation (TECHEVAL) of the product conducted with hardware and validated software which is representative of the production model to identify technical deficiencies and determine whether the design meets technical specifications and requirements. TECHEVAL also provides a major source of data for certification of readiness for Operational Evaluation (OPEVAL) and production which follow.

Test and inspection during development is an evolutionary process which becomes more controlled and specific as the item design becomes more mature. Preliminary testing of A_o is actually performed prior to Milestone II to validate engineering analyses, develop information on a specific design or technology, or to "grow" the reliability or maintainability of a design configuration. This type of early development testing may continue into the FSD phase.

Test and evaluation conducted during the D&V phase, however, was intended to determine and record critical parameters of a design related to A_o. These D&V tests evaluated the actual functions of an item against the intended functions of that item which had been established through engineering analyses. During the D&V phase and early in the FSD phase, it is desirable that the designer be given considerable latitude to work out and correct problems and design deficiencies (within LCC constraints) so that a satisfactory design evolves. The important element in this development or growth testing is to obtain and document the engineering data which will ensure achievement of reliability, maintainability, or supportability in the final product. Data obtained during test and inspection is utilized to provide feedback for changes in design in order to establish a final design which will achieve the desired A_o threshold. The information on the component characteristics of the product design are established in the Type B equipment development specifications, LSAR, and the ILSP. These specifications of reliability, maintainability, and supportability characteristics of the system design are used to support development testing in the FSD phase.

3. Conduct Operational Testing and Evaluation

Third, operational testing and evaluation must be conducted to determine the system's viability in the actual Navy Fleet environment. COMOPTEVFOR is responsible for estimating a system's operational effectivensss and operational suitability. OPNAVINST 3960.10C (NOTAL) defines operational effectiveness and operational suitability as follows:

a. Operational effectiveness is the system's capability to perform its intended function effectively over the expected range of operational circumstances, in the expected environment, and in the faces of the expected threat, including countermeasures.

b. Operational suitability is the capability of the system, when operated and maintained by typical Fleet personnel in the expected numbers and of the expected experience level, to be reliable, maintainable, operationally available, logistically supportable when deployed, compatible, and interoperable.

COMOPTEVFOR tests and evaluates systems, not components or black boxes. Thus, in general, only a system level A_o threshold should be established for OT&E. For large systems, however it may also be appropriate to have subsystem level A_o thresholds. COMOPTEVFOR is responsible for evaluating all Acquisition Category (ACAT) I, II, III, and IV systems. OT&E is conducted in four phases, OT-I through OT-IV, as described in OPNAVINST 3960.10C

OT-I is Initial Operational Test and Evaluation (IOT&E) conducted on advanced development models, brassboards, or surrogate systems. The primary objectives of OT-I are to provide an early assessment of potential operational effectiveness and operational suitability to assist decision makers at Milestone II. Sponsors should have specified A_o in OT-I to facilitate A_o analysis prior to Milestone II. Since the system configuration is probably far from its completed state and maintenance by the contractor is often necessary, the requirement for the use of Fleet-type personnel during system maintenance is exempted during early OT&E, in particular, OT-I. Thus, a quantitative estimate of A_o reflecting standard Fleet operations often cannot be made during OT&E until OT-II.

OT-II is IOT&E conducted to directly support Milestone III decisions. For all systems, OT-II concludes with a formal OPEVAL conducted using production-representative hardware, validated software, maintenance and support equipment planned for Fleet use, and the logistic support intended for system support after deployment. OPEVAL objectives include demonstrating system operational effectiveness and operational suitability.

OT-III is Follow-on Operational Test and Evaluation (FOT&E) conducted after OPEVAL but before production systems are available for testing. Specific OT-III objectives include verification of A_o thresholds if Fleet Integrated Logistics Support (ILS) systems were not available for OPEVAL.

OT-IV is FOT&E conducted on production systems. A principal objective of OT-IV is validation of the operational effectiveness and operational suitability of production systems, including A_o thresholds.

Basic Data Requirements

To help resolve critical issues, COMOPTEVFOR is required by OPNAVINST 5440.47F (NOTAL) to advise CNO on the adequacy of planned Test and Evaluation (T&E). This means that COMOPTEVFOR has input into all acquisition program documents (TOR, OR, JMSNS, DOP, TLR, TLS, SCP, DCP, TEMP, PEDS, CDS, Mini-NDCP, IPS). The inputs, including A_o inputs, are made both formally through comment letters and informally through liaison at the working level with program Sponsors and development activities.

For the Sponsor, the Test and Evaluation Master Plan (TEMP) is an extremely important document for the acquisition program. TEMP approval constitutes CNO direction to fund and execute the T&E, and is a contract between the development activities and COMOPTEVFOR on the T&E. The TEMP's basic purpose is to combine the Developing Agency's Developmental Test and Evaluation (DT&E) and COMOPTEVFOR's OT&E into one integrated document approved by CNO. Because of the close relationship between developmental testing and operational testing, the Sponsor must ensure early and continuing liaison with the Operational Test and Evaluation Force (OPTEVFOR) and the Program Manager so that OPEVAL requirements are identified and integrated into the program with proper support budgeting. The Program Manager will provide COMOPTEVFOR with all significant developmental test results and will establish a schedule which will allow correction of all critical deficiencies related to A_o which were discovered in TECHEVAL and which must be eliminated prior to OPEVAL.

The development activities and COMOPTEVFOR have independent authority within their own fields; each is responsible for his own sections in the TEMP. As in earlier acquisition documents for a system in the acquisition process (e.g., OR), the TEMP contains separate thresholds for dominant system characteristics for DT&E and OT&E. The measures are chosen by the development activity for DT&E and by COMOPTEVFOR for OT&E. The numerical levels for both are established by the Sponsor.

While the Sponsor is specifically responsible for establishing system A_o threshold values, COMOPTEVFOR is responsible for measuring the actual A_o of systems, and at a minimum, reporting the results at Milestone III decision meetings. COMOPTEVFOR will check that all DT&E and OT&E thresholds are both quantified and consistent, and that OT&E threshold values makes sense from an operational view-point. Although COMOPTEVFOR does not set thresholds, COMOPTEVFOR comments upon them if they seem inappropriate. Comments are generally not based upon documented warfare analyses, but instead upon the Operational Test Director's (OTD's) judgment based upon his Fleet experience. The OTD makes sure that the Fleet operator's viewpoint is not lost as a program moves within the acquisition process.

With the TEMP as the basic testing document, COMOPTEVFOR writes and promulgates the actual test plan, conducts (or has conducted for him) the operational testing, and evaluates and issues test results in a COMOPTEVFOR Evaluation Report. In particular, the COMOPTEVFOR Evaluation Report states whether or not the system has met each threshold, including that for A_o. Then, based upon these results, COMOPTEVFOR states whether or not a recommendation to procure the system is supported.

COMOPTEVFOR uses data collected during operational testing to calculate A_o. On occasion, DT&E data are combined with OT data when COMOPTEVFOR judges that it is representative of operational performance. Although COMOPTEVFOR strives to test systems in as operational an environment as possible, real-world constraints generally impose limitations that prevent an ideal test. Common test constraints expected to affect A_o measurement are short test time, unrealistic levels of system stress, and unrealistic logistics. COMOPTEVFOR compensates for such limitations by explicitly citing them in the Evaluation Report; however, COMOPTEVFOR usually does not model A_O, use a k-factor to convert operating time to calendar time, or apply statistics. A_O is calculated and reported precisely as measured during testing, and this number is compared to the A_O threshold.

Since logistic delay times can have significant effects upon A_O, COMOPTEVFOR's approach to unrealistic logistics is particularly important. COMOPTEVFOR recognizes that systems designated for OT&E in a Fleet unit are usually supported by a package of spares assembled by the manufacturer that does not necessarily represent the onboard spares of the ultimate installation. Thus, OTDs carefully monitor the spares from the package assembled by the manufacturer and compare the type and number of spares actually used to a Navy-prepared Allowance Parts List (APL), if available. The Sponsor must ensure compatibility of the sparing approach. As stated in the proceeding paragraph, any noted discrepancies are usually handled solely by acknowledging them as limitations to scope.

The level of detail presented on the testing and calculation of A_O varies within the sections of a COMOPTEVFOR Evaluation Report. The letter at the front of the report usually just states the measured A_O and compares it to the threshold. Within the Report Details, the Scope of Evaluation section (Chapter 3) cites the evaluation criteria, detailing such information as what constitutes critical and major failures, and also cites limitations to scope. The Test and Results section (Chapter 4) of the Evaluation Report summarizes the data base. Significant raw test data will be included as an appendix based on the judgment of the OTD.

Accomplishing Key Action Steps

1. Finalize System Design and Logistics Support Plans

   a. Based on the results of developmental testing, the Sponsor should review the Type C specifications for the system to ensure that all design changes required are consistent with mission requirements and the A_O threshold established.

   b. The Sponsor should also review the final LSAR to validate that projected MLDT estimates are consistent with A_O requirements and that final support planning is realistic and fully documented.

2. Complete Developmental Testing

In the refinement of the A_O threshold prior to Milestone III, the Sponsor should review and validate that the following six critical issues or areas have been properly addressed:

   a. Completeness and accuracy of development test data. Test data from development tests, including test conditions, significant events and problems, should be meticulously recorded, analyzed, and maintained by the Program Manager in the integrated data system. Explicit requirements for recording and reporting the results of development tests must be established by the Program Manager in FSD contracts.

   b. Completeness of testing for potential growth in system reliability. Reliability growth testing is essential and, once feasibility of the design concept to achieve A_O threshold is verified, engineering evaluation tests must be planned and implemented by the Program Manager to identify and remove significant failure modes in the design configuration.

c. System reliability, which is a part of the A_o, must be validated by test results. Reliability qualification tests are performed on items to demonstrate that the design will be able to meet or exceed A_o requirements in the operational environment. The reliability qualification test program should be verified so that, upon completion, the risk of failing any reliability demonstration testing can be certified as very low.

d. For systems with high-technical risks, reliability testing should be extended to the use of models. The fabrication and test of one or more Engineering Development Models (EDM) followed by the fabrication and test of one or more pilot production models should be confirmed by the Sponsor. For programs of lesser risk, it may involve pilot production models only. Testing is performed on EDMs to reduce the design risks and uncertainties prior to fabrication of a more representative production model, and to verify attainment of technical performance objectives in the components, subsystem, interfaces, and at ths total system level.

e. Maintainability testing must be complete and well documented. Maintainability demonstration tests are performed by the Program Manager to demonstrate that maintainability characteristics of the product meet contractual maintainability requirements. The specific approach used can range from limited controlled tests to an extensive controlled field test of the product. These tests should provide the Sponsor with quantitative estimates of maintainability parameters such as corrective maintenance downtime, fault isolation time, failed item replacement, and checkout time. Maintenance skills, spares provisioning, sequence of fault occurrences, and other relevant conditions should be reviewed to ensure they represent expected conditions for the operational Fleet system.

f. Technical evaluation test results must be complete and the data must be checked to be sure it is consistent with A_o threshold projections. The final phase of OT&E of the pilot production models is Technical Evaluation (TECHEVAL), which is conducted in the system's intended operational environment. For shipboard systems, TECHEVAL is usually conducted.in an active Fleet ship in at-sea exercises to verify that the system design that is planned for production meets technical performance requirements, and to verify that the system is ready for OPEVAL. TECHEVAL plans and results should be carefully reviewed by the Sponsor to ensure the compatibility of the system with its environment, interoperability with other systems, and the soundness of logistic support. The importance and visibility of TECHEVAL, as well as the expense and logistic support required demand a well written test plan by the Program Manager. Systems often fail OPEVAL because latent technical or logistic problems were not discovered in a poorly planned TECHEVAL. Sponsors should be aware that many of the problems encountered during TECHEVAL may be caused by the temporary or artificial nature of the installation. While the Program Manager may discount such problems because they are not expected to reappear in the production installations, they nevertheless reduce the demonstrated reliability, detract from the perceived system A_o capabilities, and jeopardize test effectiveness. The TECHEVAL/OPEVAL system, although conducted with a prototype, should be representative of the planned production configuration, including spare parts support and preliminary technical manuals. The Program Manager must also ensure that the contractor has been required to have additional spare parts available, in case of unanticipated failures in testing. Since a production line does not yet exist, spare parts support must be planned well in advance to ensure that they will be available. One of the purposes of the TEMP is to force the Program Manager to identify the resources required for TECHEVAL/OPEVAL early in the program so that they can be routinely requested in the Planning, Programming, and Budgeting System (PPBS) cycle.

3. Conduct Operational Testing and Evaluation

a. Operational evaluation test results must be complete and the data consistent with A_O threshold projections. OPEVAL is usually conducted on the same hardware as TECHEVAL. The results of TECHEVAL are used by the Operational Test Readiness Review Board to judge whether the system is ready for OPEVAL. OPNAVINST 3960.10C, establishes the requirement for the SYSCOM's to provide certification of readiness of each system to enter its OPEVAL. The certification is made to the CNO (OP-098), usually by naval message, with an information copy sent to OPTEVFOR, the Sponsor, and other interested commands.

b. Clearly, significant linkages exist between our discussions of A_O development and analysis and the policies and procedures utilized to test system A_O during the acquisition process. To be useful in the refinement of A_O thresholds, these tests must focus separately on the elements of the A_O index. Each element (MTBF, MTTR, and MLDT) should be tested and confirmed during the test process and this requirement should be reflected in the TEMP. While the Program Manager has the responsibility to establish testing requirements in the TEMP, the Sponsor has the responsibility to ensure that it is spelled out clearly, that testing is executed, and that results are utilized properly in reality at Milestone III decision to deploy the system. By separately evaluating the elements of A_O in the test process, the Sponsor can react to the potential inability of the system to perform as required in one or more of the three areas.

Documentation Required

At Milestone III, a major decision must be made to proceed with production (or limited production) and deployment of the system. To facilitate this decision a series of major supporting documents are required by the Sponsor:

- DCP/NDCP
- Integrated Program Summary
- TEMP
- COMOPTEVFOR Evaluation Report

- Approval for Production (AFP)/Approval for Limited Production (AFLP) action sheet.

At a lower level of detail are a series of foundation documents, plans, and audits which provide the Sponsor with the necessary back-up data to effectively evaluate the comprehensiveness and adequacy of the major supporting documents. These back-up sources of information include the following:

1. Updated ILS Plan (ILSP), Supply Support Management Plan (SSMP), and Operational Logistics Support Summary (OLSS). A fully developed ILSP, SSMP, and a preliminary OLSS must be available by the end of the FSD phase. The Program Manager is responsible for developing the ILSP and OLSS. The Program Support Inventory Control Point (PSICP) is responsible for developing the SSMP. The OLSS is a user-oriented logistics document whose purpose is to provide information and guidance for using and supporting activities on the application of logistic support resources required to meet mission goals.

2. Level of Repair Analysis (LORA). The LORA must be completed in conjunction with the LSA and in accordance with MIL-STD-1390. LORA is particularly important to supply support, and it provides the initial basis for maintenance planning. By analyzing data related to economic and maintenance considerations/constraints, LORA enables decision on repair, replacements or discard of components, sites, and skills for performing the appropriate level of maintenance. The PSICP needs this information to complete the provisioning process for ths system and equipment, to load failure rate predictions into its inventory model programs, and to determine stocking levels.

3. Completed Maintenance Plan. Development and approval of the preliminary maintenance plan (as provided by mechanized LSA output) must be completed by Milestone III. It must reflect planning and methodology necessary to ensure conformance to the established maintenance concept and maintainability requirements for the specific acquisition; consistency with requirements of appropriate maintenance planning directives, instructions, and standards; and incorporation of inputs from the LSA and LORA.

4. Provisioning Computation. The provisioning computation method is determined and the Provisioning Requirements Statement (PRS) is prepared. The PRS must be prepared for inclusion in the production contract. PRS approval must be obtained from the respective SYSCOM logistics directorate. The PRS gives the contractor specific guidance on the exact provisioning information and Provisioning Technical Documentation (PTD) required by the government. Included in this guidance are methods to be used in the generation of provisioning data and the range and depth of the required parts. Inputs required in the development of the PTD are specified in MIL-STD-1388 and MIL-STD-1561.

5. A_o Sparing Analysis. An analysis of A_o must be conducted using, where appropriate and necessary, historic data from similar weapon systems (BCS). Results of the analysis must be reported to the Sponsor, as well as recommendations for specific actions necessary to achieve A_o thresholds. Previously unbudgeted costs and extraordinary support requirements that

are indicated by the analyses must be stated. Alternative courses of action with associated A_o expectations and cost considerations must also be provided to the Sponsor.

6. Logistic Support Summary. The logistic support summary is required as an input for the Milestone III decision. It includes a summary of the logistic support concept, the logistic schedule, logistic Support Management plan, and a logistic support life-cycle cost profile.

7. ILS Audit. The most comprehensive audit of the logistics system is conducted prior to Milestone III. ACAT I and II programs will be audited by the OPNAV Logistics Review Group (LRG). ACAT III and IV programs will receive audits at the SYSCOM level.

MONITORING AND EVALUATING A_o REQUIREMENTS

Key Action Steps

In the FSD phase of the systems acquisition process, the Sponsor must monitor and evaluate the final evolution of the A_o index which should be finalized prior to Milestone III. Two major actions are required:

1. Confirm That All Reliability, Maintainability, and Supportability Analysis is Complete

   a. The Logistics Support Analysis (LSA) (see MIL-STD-1388-1A) is completed by the Program Manager. Figure 4-2 illustrates the major LSA tasks during the Full-Scale Development phase.

   b. The Maintainability Design Analysis (see MIL-STD-470A), begun in the previous stage, is completed by the Program Manager.

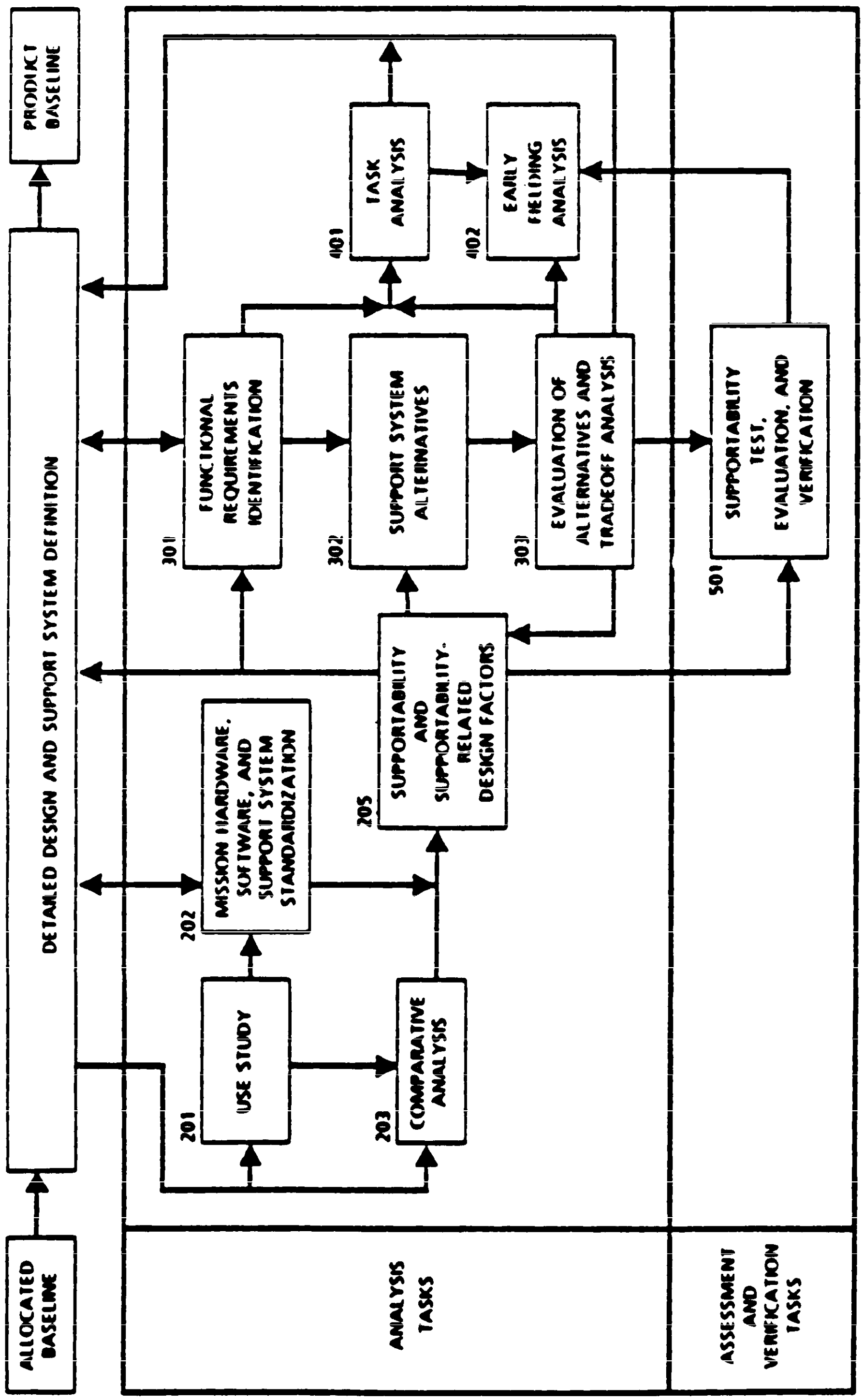
   c. Reliability Design Analysis (see MIL-STD-785B) is completed by the Program Manager.

2. Confirm Test Results Consistency With A_o Requirements

   a. The testing of the system, as defined and discussed in the TEMP, is conducted to determine the operational viability of the overall system

   b. The reasonableness of the separate components of the A_o index (MTBF, MTTR, MLDT) have been confirmed under expected Fleet operating conditions.

This independent assessment is perhaps the major step required during the FSD to allow the Sponsor to reach a Milestone III decision to deploy the system with the assurance that it can perform its intended mission. To be accurate, system operational performance should be tested in combat. Obviously, this will rarely happen. Consequently, estimating operational performance on the basis of testing to support the acquisition process must be based on some artificialities. The goal, however, is to be able to draw conclusions from a test that will be in agreement with those that would be observed if the system were deployed and used as planned.



NOTES:
1. Tasks 101, 102, and 103 are management activities that are an integral part of the LSA process, though not shown in this figure.
2. Task 402 provides data to ILS management.

FIG. 4-2: LOGISTIC SUPPORT ANALYSIS PROCESS FLOW CHART: FULL-SCALE DEVELOPMENT PHASE

The Navy's OT&E is limited by money, assets, time, and politics/geography. Thus, while OT&E will be performed in an operational environment, it may not be the most representative one(s). The simulated threat often will not simulate the most current threat (much less the projected threat), and the quality of the simulation may be questionable. To complete testing in time to support a scheduled decision point, maintenance and logistic support may not reflect what is planned for the Fleet. And very seldom will sufficient test time be available to generate highly accurate estimates of performance.

It can be suggested that since artificialities must be introduced anyway, the best way to estimate system operational performance is to make the test completely artificial--to model. Modeling appears to be an extremely alluring alternative: several of the limitations of OT&E need not be present in models; it is often much less expensive than conducting OT&E; and it can often generate a result based on more trials.

The fundamental shortfall of modeling is the "omitted variable problem." A model can only be as realistic as the model maker can conceive the operating environment, the threat, and so on. Conditions that cannot be conceived cannot be modeled and complex interactions can often not be modeled. This is a non-trivial point and the very reason for OT&E. The potential cost/impact of believing erroneous performance estimates is unacceptably high, and not modeling a subtle interaction that results in a system failure is embarrassingly common. Several examples are: satellites that don't work because of unanticipated frequency interference; warheads that are found to be vulnerable to electromagnetic radiation; aircraft that won't work because of corrosion from salty air; and guns that don't fire because they jam from the grime accumulated in normal use. The way to identify omitted variables for system performance is to collect operational data, in which case, operational testing would have to be conducted. Actual OT&E is, therefore, the most reasonable way to estimate system operational performance, particularly while a system is in the acquisition process.

Basic Data Requirements

An OT&E Evaluation Report gives the Sponsor a snapshot of system demonstrated performance. However, Evaluation Reports are not just lists of test results. They identify the decision points the OT&E was conducted to support, the critical operational issues that OT&E intended to address, the performance thresholds against and limitations to the actual scope of the OT&E. Each report contains a summary of how the tests were conducted and how extensive they were. Test results and conclusions are given. The test results may or may not form the complete basis for the conclusions since COMOPTEVFOR's operational experience is an extremely important factor in the conclusions reached. However, the Evaluation Report explicitly presents the operational reasoning when operational experience causes the conclusions and recommendations to not follow directly from the results.

COMOPTEVFOR's Evaluation Report allows CNO (and other decision makers) to understand the value and limitations of the OT&E. It is used along with other information, such as cost constraints, to allow sound decisions on system acquisition.

Accomplishing Key Action Steps

1. Confirm That All Reliability, Maintainability, and Supportability Analysis is Complete

    a. Review the ILSP, SSMP, OLSS, and Integrated Program Summary

b. Verify results of the ILS audit.

2. Confirm Test Results Consistency With A_O Requirements

OPTEVFOR should ideally measure and report A_O and its components, MTBF, MTTR, and MLDT. This action, performed by OPTEVFOR, must be reviewed and evaluated by the Sponsor in reaching a Milestone III decision. As described in the preceding chapters, the A_O of a system is a function of the stress the system experiences and which causes it to fail, and the sources of system downtime. A_O of complex systems such as those used by the Navy cannot be uniformly well estimated by a single, simple equation. Instead, as we have seen there are different A_O estimates for each of three categories of systems: Continuous Use, Intermittent Use, and Impulse.

Continuous-Use Systems

For continuous-use systems, OPTEVFOR will measure A_O as

$$A_O = \frac{\text{uptime}}{\text{uptime} + \text{downtime}}$$

COMOPTEVFOR defines uptime as the time during which the system is operating or, if in standby or off, can be brought into operating status within an acceptable delay. Downtime includes time during which the system cannot be called upon to perform its mission due to a critical (mission-aborting) failure or a major (mission-degrading) failure. The duration of downtime, of course, is dependent upon active repair time and acquisition of onboard and/or offboard parts (logistics).

Besides unschedule downtime, there are other downtimes considered in test results. Based on the TEMP specification, the time during which the system is scheduled to be unavailable, such as during preventative maintenance, may be counted as uptime, downtime, or "no-test" time. In addition, some time during which the system is scheduled to be available but isn't, such as when the system is used for training or is being documented, may be considered as uptime, downtime, or "no-test" time based upon the OTD's judgment.

Intermittent-Use Systems

This class of systems is probably the largest class of Naval systems--and is also the most complex. For these systems OPTEVFOR provides two estimates of system readiness. One of the measures is A_O as we have defined it in this handbook. The second reflects the percentage of time the tested system actually began an intended mission. Both measures are useful and important to our understanding of how well the system will perform.

The traditional readiness measure, A_O is computed as

$$A_O = \frac{\text{uptime}}{\text{uptime} + \text{downtime}}$$

When this equation is used with intermittent-use systems it is sensitive to how downtime is counted. The problem arises because failures in intermittent-use systems may not be discovered at the time they occur. In particular, if a system is discovered to be inoperative when it is turned on, it is usually not known whether it failed when lasted turned off, when it was off/in standby, or when it was turned on. Various approaches have been taken to address this question. As we pointed out in an earlier section, downtime commences when a failure is discovered. Not only does this add consistency to our A_O analyses, but it makes the most sense to credit the system as being up until it is explicitly known to be down, since the operating Navy assumes and acts as if equipment is up until it is known to be done.

The second measure of readiness given in OPTEVFOR test results is

$$A_I = \frac{\text{number of successful starts}}{\text{number of desired starts}} \quad 1$$

The number of desired starts includes not only successful starts and starts actually attempted under the assumption that the system was able to operated, but also starts that would have been attempted but were not because the system was believed to be operative. Also, it is assumed that the demand must be independent of the assumed status of the system.

These two estimates of readiness may or may not yield the same readiness value. This is especially true if there is a pattern to the distribution of demand for the system's use. For A_O analysis, we concentrate on uptime/(uptime + downtime) as the most important measure. Nevertheless, the measure of A_I can be important since it is a measure of readiness that can tell us if A_O is adequately set for the time-phased events in a scenario that is planned for the system.

One way to view the difference between these two measures is to compare them to the two analogous measures of aircraft readiness. A_O is analogous to an aircraft FMC rate and A_I is analogous to a sortie rate in FMC status. (For this analogy, sortie rate corresponds to the percentage of sorties that can be started with FMC aircraft.)

To avoid confusion, the Sponsor should specify the specific measure to be reported, A_O or A_I, in the TEMP. But COMOPTEVFOR is in a good position to judge which equation provides the best/most informative estimate of readiness because operational testing exposes previously unpredicted behavior.

Expendable Systems

Expendable systems, sometimes called impulse systems, generally operate for very short times and have no or extremely little maintenance and logistic support. When they are employed (expended) they either work or they do not. The following equation is used in testing to measure the A_O of such systems:

$$A_O = \frac{\text{number of successful employments}}{\text{number of attempted employments}}$$

COMOPTEVFOR defines the number of attempted employments as successful and unsuccessful employments that were actually attempted as well as employments that would have been attempted if the system had been believed to have been operative. Judgment tends to play a substantial role in determining/estimating the number of employments that were not attempted while the system was

1. A_I stands for availability-intermitten-use systems and should not be confused with A_i, inherent availability.

believed to be inoperative.

A_o Component Measurements

To provide maximum usefulness to the Sponsor in evaluating the A_o of new systems, OPTEVFOR must be required to both:

1. Test A_o using the aggregate measures discussed previously

2. Evaluate the system to determine mean values (and variances) of the three factors (MTBF, MTTR, and MLDT) that make-up the A_o composite index.

Both issues relate to the probability that a system will be ready when needed. Both issues are important to not only the operating Fleet which will be using the system but also the Sponsor faced with acquisition management. In today's acquisition environment, the testing process must provide quantitative data both at the aggregate level (A_o under alternative TEMP specifications) and at the individual element level (MTBF/MTTR/MLDT). Consequently, COMOPTEVFOR should be requested via the TEMP to develop overall A_o estimates and to quantify MTBF/MTTR/MLDT in order to provide the most complete possible estimate of the probability a system will be ready for use when needed.

Limitations on cost and time often force OT&E, and in particular OPEVAL, to be conducted using unrealistic logistic support of the system. Since Logistics can significantly affect A_o, OP-04 is directed in OPNAVINST 5000.49A to:

> Assess the results of COMOPTEVFOR's operational test and evaluation of A_o, conduct analysis as necessary to account for any variations between the logistic support experienced in OT&E and that scheduled for the Fleet, and report results with recommendations for any corrective action needed at the Milestone III decision meetings.

Since OP-04's responsibility can include modifying COMOPTEVFOR's reported A_o, it is reasonable to make the modification using the same basic equation(s) used for measuring A_o. Modification of COMOPTEVFOR's demonstrated A_o focuses upon modifying downtimes. For any of the A_o equations, downtimes can be modified at various levels of specificity. Which level is chosen should depend on how accurately downtime can be predicted or modified to reflect the system's projected logistic support in the Fleet.

Quick Modifications

The most general modification can be accomplished by substituting single-point estimates of downtime due to logistic delay (MLDT) and downtime due to repair (MTTR) for the demonstrated logistic delay times and repair times for individual failures. For this reevaluation of A_o the Program Manager must specify in the TEMP that average meantime between (critical) failure, meantime to repair, and mean logistic delay times are to be reported.

Then, using OPTEVFOR's observed MTBF or MTBCF and estimates of MTTR and MLDT, estimate the A_o that would have been achieved if the observed repair and logistic delay times had actually been our estimates. The estimates that we use for MTTR and MLDT come from two possible sources. They can be the default values or tailored estimates made on the basis of engineering estimates for MTTR and the detailed integrated logistic support analysis which will take into account the manpower, intermediate- and depot-level maintenance, transportation, and spare parts planned for the system.

More detailed modification to A_O estimates may be accomplished using timelines. First, in each case, demonstrated OT&E data must be provided so that a timeline of the OT can be reconstructed. To accomplish this, the following OT&E data is required and must be requested in the TEMP.

1. Time of each demand
2. Time of each failure
3. Downtime for each failure due to corrective maintenance (exclusive of logistic delay)
4. Downtime due to logistics for each failure
5. Downtime for each failure exclusive of downtime due to corrective maintenance or logistics for each failures.

With this data, the timeline can be modified in two ways. The precise way in which we modify will depend on the planned use of the system.

For continuous-use and intermittent-use systems which are called upon to function randomly, we can replace repair times and logistic delay times by our estimates of what these times would be under assumed variations in maintenance and logistic support. We can approximate repair and logistic delay time based on the type of failure that occurs. Then total uptime and total downtime can be computed from the modified timeline and A_O reapproximated. Figure 4-3 below gives an illustration of this procedure.

Observed timeline		Modified timeline	
Time	Occurance	Time	Occurance
0	Operation begins	0	Operation begins
5	Failure 1 occurs	5	Failure 1 occurs
10	Logistic delay	8	Modified logistic delay
11	Repair completed	10	Modified repair completed
18	Failure 2 occurs	17	Failure 2 occurs
50	Logistic delay	27	Modified logistic delay
52	Repair completed	29	Modified repair completed

FIG. 4-3: AN EXAMPLE OF AN OBSERVED AND MODIFIED TIMELINE

Note that in Figure 4-3 our modified timeline contains only 29 time units, primarily because the logistic delay observed for failure 2 was reestimated to be 10 units instead of 32.

For this example,

$$\text{observed } A_O = \frac{12}{52} = 0.23$$

$$\text{modified } A_O = \frac{12}{29} = 0.41$$

For intermittent-use systems which have a pattern to their demand for use, the timeline is modified to account for the particular requirements made on the operation of the system in the scenario used in testing. In this case, the calendar time between failures is modified to account for the observed operating time between failure, the standby or no-use time, and the explicit times the system is required to perform in the scenario. In this case, observed operating time between failures will not change, but because of the operational requirements, calendar time between failure may change. In any event, observed maintenance or logistic delay times may be replaced by best estimates and an anticipated uptime/(uptime + downtime) may be computed.

Note that the modified timelines may not fully represent the planned scenario for the system. Nevertheless, they do represent the strain and stress put on the system being tested.

Finally, the modified timeline can also be used to reestimate AI for intermittent use systems.

For impulse systems

$$A_O = \frac{\text{number of employments}}{\text{number of desired employments}}$$

is the appropriate equation for estimating A_O. Expendables in the simplest sense are only demanded once and are never repaired. If it doesn't work when demanded, it is too late to repair it. For these systems, logistics cannot affect A_O but the inventory level of the system can. There are expendables, though, in which failures can be identified before the system is demanded--perhaps through BITE. These systems are available if repaired before demanded. Thus, logistic delay may affect their A_O.

To estimate the effect of modified logistic and repair delay, first estimate the modified downtimes due to logistics and repair, then a timeline must be constructed based on OT&E demonstrated uptime periods and downtime periods as we did for continuous and intermittent use systems to determine the effect of variations in logistic and maintenance support. For this case, you may also want to consider the inventory level of the impulse system as a factor in the number of (successful) employments.

Finally, in reviewing test planning and test results, the Sponsor should ensure the following 12 issues are adequately addressed:

1. Is A_O target set in TEMP?

2. What A_O estimates are required given different support alternatives?

3. Are specific A_O elements requested as additional information from OPTEVFOR?

    a. MTBF

b. MTTR

c. MLDT

d. Timeline of events that relate to A_o

- Scenario planned
- Scenario accomplished
- Failures and times of failures.

4. Are A_o thresholds established for the entire system and for critical/major subsystems?

   a. During OT-O/I

   b. During OT-II

   c. During OT-III

   d. During OT-IV

5. Are A_o thresholds in the TEMP for major/critical subsystems as well as the system as a whole compatible with another?

6. Is A_o to be measured by COMOPTEVFOR during OT&E clearly specified? Is the rationale for selecting a particular A_o measure well documented?

7. Are Fleet ILS during OT&E representative of that actually scheduled for the Fleet? If not, are variations spelled out and, as appropriate, effects estimated cited in the Evaluation Report as a limitation to the score of the OT&E?

8. When A_o is estimated using uptime/(uptime + downtime), does the Evaluation Report contain both total downtime and downtime due to logistics?

9. Has the Deputy CNO (Logistics)(OP-04) approved "certification for OPEVAL" and do program preparations allow for COMOPTEVFOR to make a sound assessment of A_o?

10. If the logistic support demonstrated during OT&E varied from that scheduled for the Fleet, has OP-04 analyzed/modified the A_o value demonstrated during OT&E and reported results and recommendations for any corrective action needed at the Milestone III decision meeting?

11. If OP-04 has reason to believe that there will be a need to analyze/modify the A_o demonstrated during OT&E, has advance information beyond that which is normally contained in a COMOPTEVFOR Evaluation Report been identified by OP-04?

12. Has this additional data from COMOPTEVFOR been requested before OT&E has begun?

Documentation Required

Documentation requirements for A_o thresholds at Milestone III were discussed in an earlier section.

A_o COST TRADE-OFF ANALYSIS

Key Action Steps

1. Validate Final System Life-Cycle Cost Projections

During the final phase of systems acquisition prior to system deployment, final life-cycle support cost estimates will be formulated by the Program Manager. Utilizing the general methodology introduced in Chapter Two, Sponsor should evaluate these cost estimates and the trade-off analysis. Essentially, previous results should be compared to those which are available in FSD and, if appropriate, funding projections revised as required. The FSD phase has two significant characteristics which affect the cost-benefit analysis process:

a. As the system design progresses from a description of required equipment function to required physical characteristics, the latitude to change the design diminishes.

b. As the design of the system and the logistics support becomes more definite, the ability to accurately estimate Life-Cycle Costs (LCC) increases.

2. Confirm Design to Cost Objective

The design to cost concept is a major element in the Program Manager's strategy to ensure cost-benefit analysis in FSD and must be validated by the Sponsor.

The design to cost concept refers to the management and control of life-cycle cost during the system development process by establishing a specific overall cost objective in a contract. Under this concept, the contractor is able to assess and trade-off future acquisition, operating, and support costs during the design process. A design to cost goal is a specific cost number (in constant dollars for a specified number of systems at a defined production rate) which is established by the Program Manager as early as possible in the acquisition process, but not later than the time of entry into the FSD phase. The design to cost objective is usually established at Milestone II.

Basic Data Requirements

The increased role of the system design agent in cost-benefit trade-off analysis during FSD requires that specific contractual requirements be established in the FSD solicitation prior to Milestone II. A full-scale design to cost effort actually begins with the requirements definition process. At this stage, production costs, key support cost factors, and quantity relationships are derived and compared with "available" resources. These early cost estimates are iterated as primary parameters during the formulation of minimum essential performance and A_o requirements for the new system or equipment. Such cost-benefit relationships are approved at Milestone II prior to FSD contract award. These actions establish cost goals for A_o and LCC which can be validated and refined for use as primary design parameters, equal to performance in priority, during FSD. As the program progresses through FSD, some cost (production and support) and performance trade-off flexibility is needed to permit development of an acceptable system within the cost constraints. The FSD contract must be structured to encourage and allow the contractor to conduct cost-benefit trade-offs based on A_o.

Accomplishing Key Action Steps

1. Validate Final System Life-Cycle Cost Projections

In FSD, cost estimates become more accurate, but the ability to change cost factors (without an unacceptable cost burden) no longer exists. Another significant factor in FSD is the evaluation of the system description which is the basis of cost estimates. As the system concept develops into system and equipment design, the system definition changes from mission operations concepts and functional descriptions into detailed engineering descriptions (drawings, materials, and dimensions). The system design agent becomes the primary source of system description. Therefore, during FSD the contractor's role in cost estimation and cost-benefit analysis is increased and assumes functions which were performed by the Program Manager in earlier phases of development.

Many cost-benefit analyses which are based on design reliability, maintainability, and supportability will be made at the desktop level of the contractor's design engineers, production managers, and logisticians. The Program Manager must establish the procedures to ensure that each desk-top decision will include a trade-off analysis to evaluate the impact on A_o and overall LCC. The Sponsor should review Program Manager procedures to ensure they are adequate.

2. Confirm the Design to Cost Objective

The Request for Proposal (RFP) which is issued by the Program Manager for FSD must (1) clearly establish the design to cost goal and (2) require the bidder to define the manner in which the design to cost requirement will be implemented. It is essential to clearly define in the FSD contract the elements covered by the design to cost goal. This definition should include the types of expense, such as direct labor, subcontracts, material, start-up cost, production tooling, LCC estimation techniques, and items of equipment covered by the goal.

Clear definition of the design to cost requirement is necessary for two reasons. First, a clear definition will prevent later misunderstanding between the government and the contractor over what was included in the contractual design to cost goal. Also, at Milestone II and III, the Program Manager must define the elements that are included in the contract design to cost goal and how they relate to the LCC estimate which is established. These elements should be reviewed and confirmed by the Sponsor.

In addition to defining the elements in the goal, the design to cost clauses in the contract set forth the assumptions upon which the figure was based, such as quantity, duration, and rate of production. While these elements may be obvious or easily derived, specifically including them in a special design to cost clause will avoid misunderstanding. These assumptions should be specifically validated by the Sponsor.

The Sponsor may obtain more detailed information on the design to cost process and LCC estimation techniques in DODD 4245.3 of 6 April 1983 (Subj: Design to Cost) (NOTAL), and NAVMATINST P-5242 (Subj: Joint Design to Cost as a Design Parameter) (NOTAL).

Documentation Required

The specific output of the cost-benefit analysis and trade-off process is the LCC estimate which is established and presented at Milestone III for the production decision. The LCC estimate at Milestone III should include a design to cost goal for the acquisition cost component, and a separate design to cost component for operating and support cost.